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Erbium:YAG Laser Trabecular Ablation (LTA) in the Surgical Treatment of Glaucoma

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Background and Objective: **Laser trabecular ablation (LTA) aims to remove trabecular tissue and to open Schlemm's canal in order to improve outflow facility in glaucomatous eyes. The purpose of our study was to investigate the pressure-reducing effect of LTA in chronic open-angle glaucoma 1 year following laser surgery.**
Study Design/Materials and Methods: **Eleven eyes of 11 patients with chronic open-angle glaucoma were treated by circumscribed laser ablation of the trabecular meshwork. We used an Erbium:YAG laser (2.94 μm) with a quartz fiber contact endoprobe (320 μm core-diameter, 385 μm coating-diameter) applying 11–30 single neighbouring laser pulses (5–7 mJ) to the trabecular meshwork by an ab-interno approach. Laser procedure was gonioscopically visualized.**
Results: **Mean maximum intraocular pressure (IOP) of all 11 patients before LTA was 36 mmHg and dropped down to 22 mmHg after a mean follow-up of 12 months following LTA; this represents an IOP decrease of 38% (*P*=0.008). The average number of medications per eye dropped from 2.8 to 1.5 per eye (*P*=0.021).**
Conclusion: **Although IOP lowering effect of Erbium:YAG laser trabecular ablation did not prove as effective as in filtering procedures, LTA might be a valuable alternative in glaucoma surgery especially in order to avoid conjunctival scarring and postoperative hypotony. Lasers Surg. Med. 23:104–110, 1998.**

Key words: glaucoma; intraocular pressure; laser surgery; trabecular meshwork

INTRODUCTION

During the last few years, the interest of antiglaucomatous surgery has more and more focused on infrared laser systems. These lasers are relatively inexpensive, they are not suspected to be carcinogenic or teratogenic, and they cause small adjacent thermal tissue damage due to a wavelength near the absorption peak of water [1,2].

The Erbium:YAG laser has been used for ab-externo sclerostomy in human open-angle glaucoma in several clinical studies [3–6]. Laser sclerostomy creates a direct fistula between the anterior chamber of the eye and the subconjunctival space. Although surgical handling and short-term results were excellent, and no major intraoperative complications occurred, a longer follow-up of >6 months revealed a remarkable failure rate of this "minimally invasive surgery" [5,6]. Another, still experimental approach might be the internal contact sclerostomy with an Erbium:YAG laser and an intraocular fiberscope [7]. This ab-interno technique would minimize the inducement of episcleral and subconjunctival fibrosis, which is one of the main causes for surgical failure after ab-externo sclerostomy.

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In contrast to laser sclerostomy, the laser ablation of the trabecular meshwork does not touch the sclera, the episclera, or the conjunctiva of the eye. Because the major portion of outflow resistance in glaucoma patients is restricted to the trabecular meshwork, photoablative trabecular surgery should be an effective and reasonable pressure-reducing surgery by facilitating direct outflow from the anterior chamber into Schlemm's canal. Laser ablation or perforation of trabecular tissue had first been performed by Krasnow using a ruby laser system [8]. Several laser systems followed, including the argon [9], the neodymium:YAG [10–12], and the excimer laser [13]. Photoablation of trabecular tissue by an Erbium:YAG laser was introduced by Hill and coworkers [14–16], who called this procedure LTA (Laser Trabecular Ablation). The functional effect of Erbium:YAG laser trabecular ablation on outflow facility in mammalian eyes could be demonstrated by in vitro and in vivo studies [15,17].

In a prospective study we performed Erbium:YAG LTA in patients with terminal open-angle glaucoma. Methods and preliminary short-term results after 6–19 weeks have been published and were promising [18]. The aim of the present study is to report the clinical outcome more than 1 year following infrared laser trabecular ablation in order to evaluate the perspective of this new antiglaucomatous laser surgery.

MATERIALS AND METHODS

An Erbium:YAG laser (2.94 μm wavelength) from Aesculap Meditec, Germany (MCL 29), producing pulses in the normal spiking mode (200 μs) was used in this study. Pulse energy was delivered by contact mode via a quartz fiber endoprobe (core-diameter 320 μm, coating-diameter 385 μm) which was articulated to a zirconium fluoride fiber (350 μm, 150 cm). The endoprobe was protected by a stationary metal tube (800 μm outer diameter). The pulse energy emitted at the fiber tip ranged between 5 mJ and 7 mJ (at the laser output between 6 mJ and 10 mJ) and was preoperatively measured with an external joulemeter (Fieldmaster, Coherent, Palo Alto, CA). In previous studies we could demonstrate that this range of pulse energy is sufficient to penetrate fully the human trabecular meshwork and to open Schlemm's canal [19]. Generally we tried to apply ~15–20 neighbouring and not overlapping single laser pulses (repetition rate 1 Hz) to the trabecular meshwork; in case of obscured visualization due to reflux bleeding, we performed <15 pulses (min. 11). If reflux bleeding was very limited, we administered >20 pulses (max. 30) supposing that reflux bleeding is the only intraoperative sign of having opened Schlemm's canal.

Eleven patients with final chronic open-angle glaucoma were treated after they had been fully informed about the experimental character of this new surgical modality. Ethical approval was provided by the Human Research and Ethics Comittee of the University of Cologne. Only patients older than 40 years with no history of uveitis, trauma, or previous trabecular surgery, and having a visual acuity of 20/200 or worse with a better function in the contralateral eye were considered for this study.

Preoperative steps were para- or retrobulbar anesthesia, a maximal miosis of the pupil, an intravenous infusion of mannitol (250 ml), and manometric oculopression (30–40 mmHg) for 10 minutes. After injection of viscoelastic (Healon GV) into the anterior chamber at the temporal 9 (right eye) or 3 (left eye) o'clock position of the peripheral cornea, the quartz endoprobe was transcamerally attached to the opposite trabecular meshwork with the aid of the operating microscope (Fig. 1). Under gonioscopic control, between 11–30 neighbouring single laser pulse were applied exerting gentle pressure along the fiber tip (Figs. 2,3). After the procedure the viscoelastic, blood, and debris were rinsed out by irrigation-aspiration maneouvres, the corneal incision was closed by a single nylon suture.

All patients were examined 1 and 6 days, 1, 3, 6, and 12 months after LTA. Topical medication following laser surgery was started with pilocarpine 1% to avoid synechiae of the treated chamber angle and steroid drops that were tapered off within 4 weeks.

For each patient, pre- and postoperative maximum intraocular pressure (IOP) was determined by the highest IOP out of five applanation measurements. Medication score represented the numbers of each topically used antiglaucomatous drugs; supplementary oral acetazolamide therapy was added up depending on dose (< 750 mg daily = 2 / 750 mg and more daily = 3).

Statistical evaluation was performed using the Wilcoxon matched pairs signed-ranks test.

RESULTS

Laser trabecular ablation was performed in 11 eyes of 11 patients with a mean age of 69±8.5

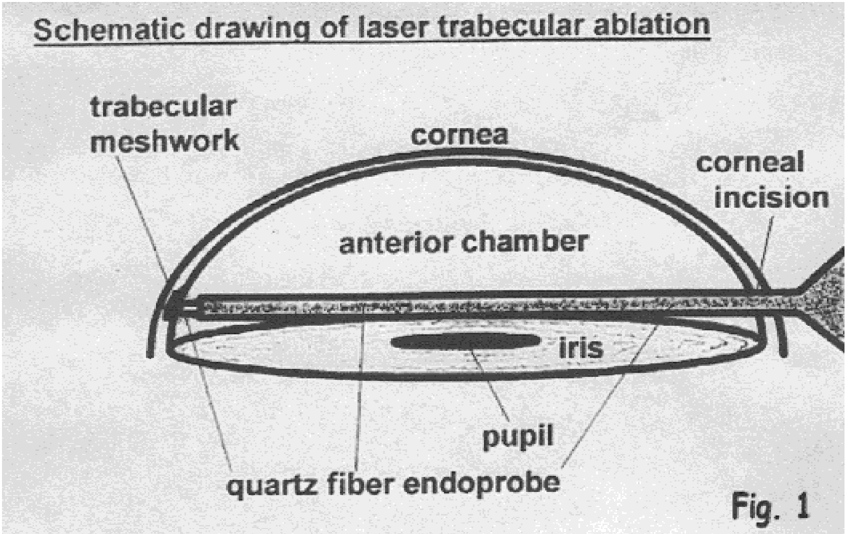

Fig. 1. Schematic illustration of ab-interno Erbium:YAG laser trabecular ablation. The quartz fiber endoprobe is inserted into the anterior chamber and touches the opposite trabecular meshwork. Between 11 and 30 neighbouring laser pulses were applied to the nasal quadrant of the chamber angle.

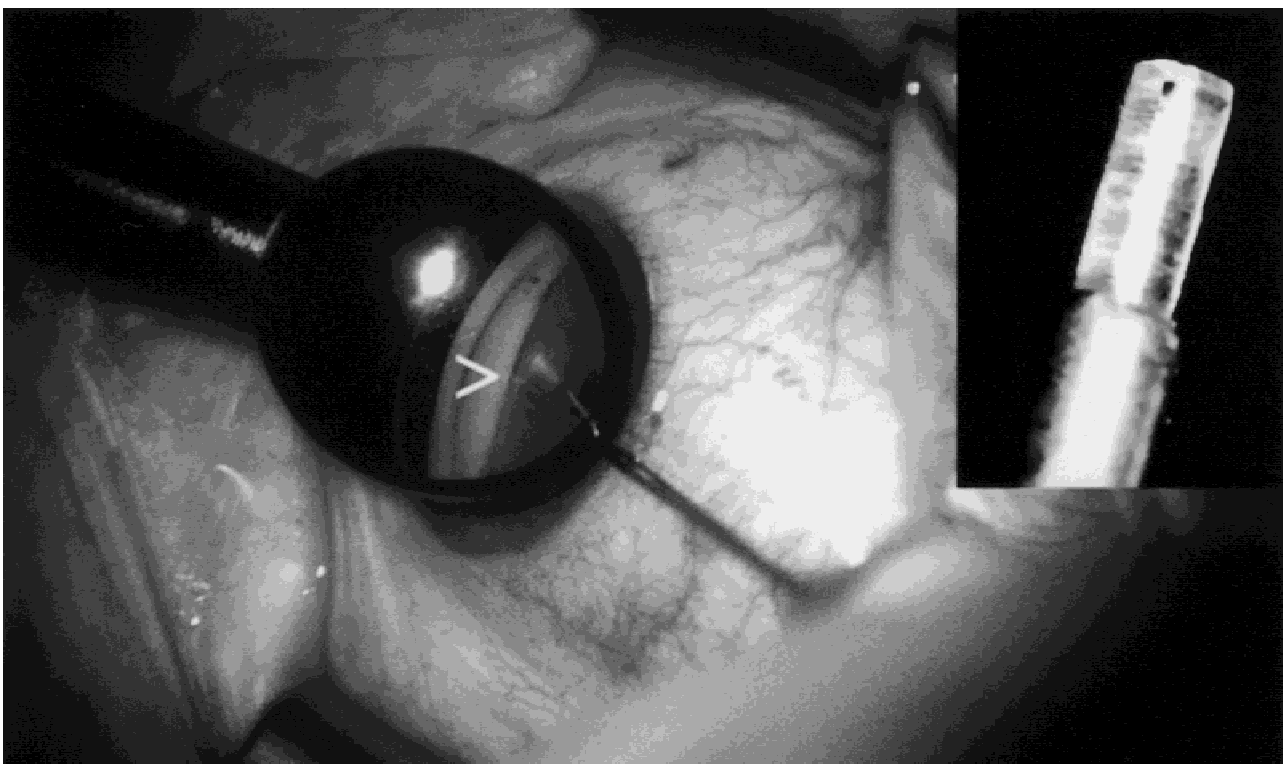

Fig. 2. After introducing the endoprobe into the anterior chamber, a gonioscopic lens is placed on the cornea in order to have insight into the chamber angle of the eye. At the end of the fiber tip, the red aiming beam is visible in front of the trabecular tissue (see arrow). The small inset shows the tip of the quartz fiber endoprobe.

years; six patients were male, five patients were female. Four patients suffered from primary open-angle glaucoma, six patients from pseudoexfoliation-glaucoma, and one patient from pigment dispersion-glaucoma. Three eyes had undergone previous ocular surgery (2× cataract surgery, 1× trabeculectomy).

Mean preoperative maximum IOP was 36.0±8.8 mmHg (range, 24–55 mmHg). Mean number of applied laser pulses was 18±5.5 (range,

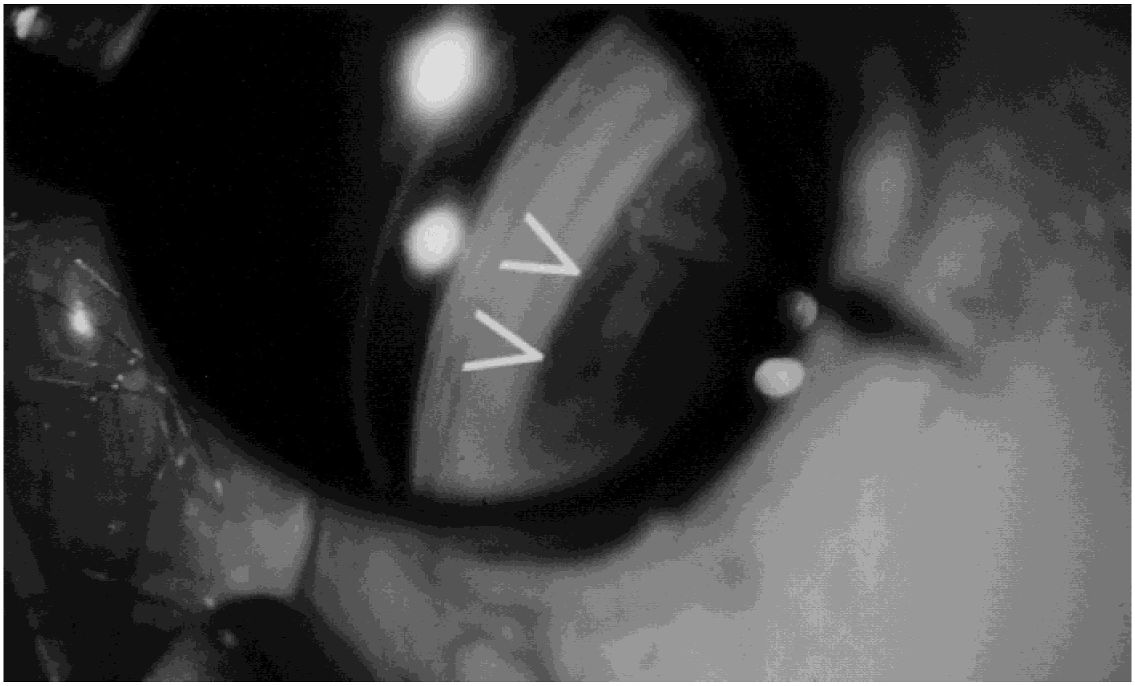

Fig. 3. After applying several single pulses to the trabecular meshwork, a moderate reflux bleeding from Schlemm's canal regularly occurs (see arrows).

11–30). Follow-up averaged 12.5 months (range, 9–15 months).

Mean maximum IOP at the end of the follow-up (12.5 months) was 22.0±7.2 mmHg (Fig. 4). This represents a percentage decrease from baseline of 38.9 %, which is statistically significant ($P = 0.008$). Average medication score per eye dropped from 2.82 (range, 1–5) to 1.46 (range, 0–2) at the end of the follow-up period, representing a 48% reduction ($P = 0.021$). At the end of the follow-up period, 7 of 11 eyes (64%) constantly maintained their IOP below 21 mmHg. In this successfully treated group, the mean maximum IOP was 17.6±1.6 mmHg (vs. 37.3±9.1 mmHg preop.) and the mean number of topically used medication was 1.43±0.54 (vs. 3.0±1.29 preop.) at the end of follow-up.

There was no statistically significant correlation between the applied numbers of laser pulses and the decrease of IOP (Fig. 5a), although the seven "successfully treated" patients had actually received a slightly larger mean number of laser pulses (18.7±5.8) than the other four patients (15.5±4.8) (Fig. 5b).

No serious intra- or postoperative complications (e.g., retinal detachment, corneal opacity, visual loss) happened in the treated eyes. The visual acuity that was 20/200 or worse preoperatively did not worsen evidently in any patient of our study group during the follow-up. In one treated eye of an 80-year-old patient, cataract had progressed 12 months following LTA and cataract surgery was performed according to the patient's wish. Very small and localized anterior synechiae were gonioscopically observed in two patients. Limited reflux bleeding from Schlemm's canal occurred in all treated eyes during LTA and was evaluated as reliable sign of full-penetrating trabecular ablation. No serious hyphema was observed and the small blood clots in the chamber angle were absorbed within days. Intraocular infection or iritis did not occur.

Due to a loss of pigmentation, the laser-induced effects within the trabecular meshwork were always gonioscopically visible during the first weeks following LTA (Fig. 6), but disappeared or were at least difficult to identify in most cases at the end of the follow-up period. No correlation was found between IOP lowering and postoperative visibility of the laser effects. In none of the treated eyes did we find any gonioscopic signs of cyclodialysis,

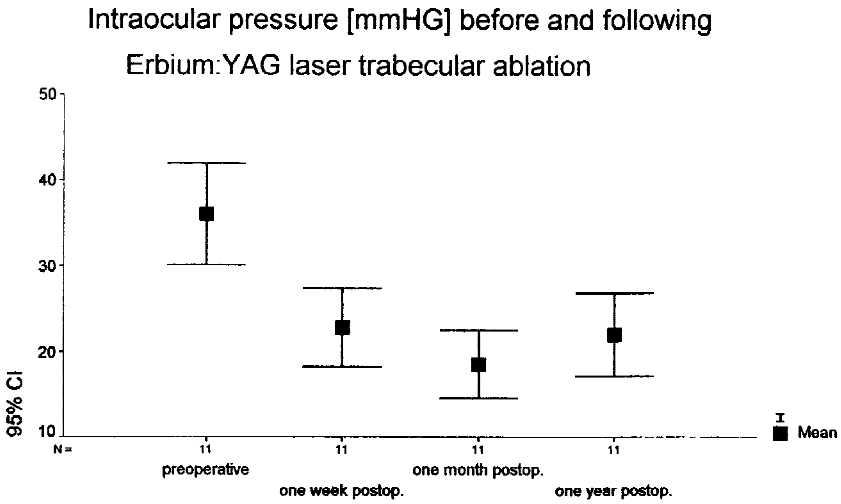

Fig. 4. Mean IOP (with 95% confidence interval) and its time course before and following Erbium:YAG laser trabecular ablation (LTA).

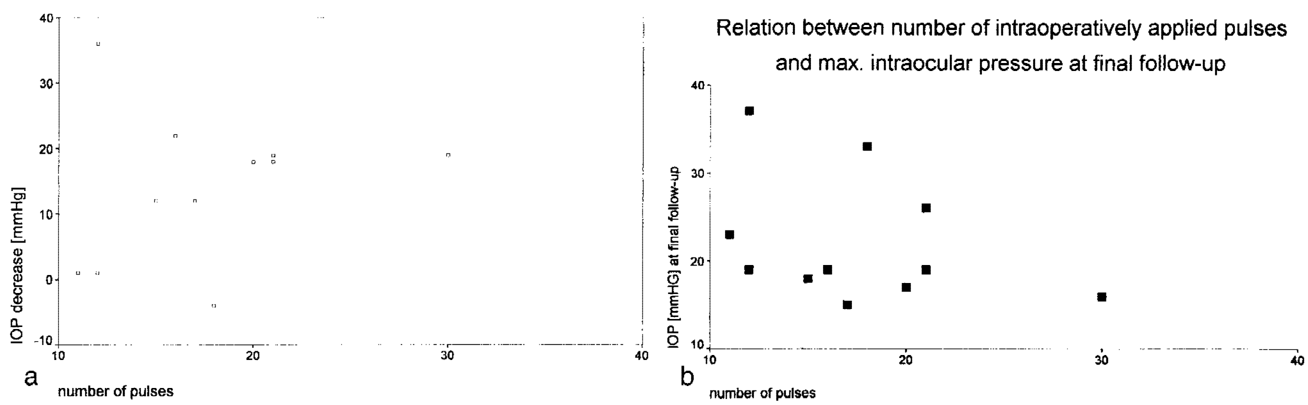

Fig. 5. Number of applied laser pulses in correlation to the relative IOP decrease (**a**) and to the absolute postoperative IOP level (**b**) after Erbium:YAG laser trabecular ablation (LTA). There seems to be a tendency to a lower IOP with more laser pulses applied, but this is not statistically significant.

and in several "successfully" treated eyes, cyclodialysis was ruled out by ultrasound biomicroscopy.

DISCUSSION

Morphological results of Erbium:YAG laser trabecular ablation in human donor eyes have been described in detail [14,16,19,20]. Using their laser system, Hill and co-workers [14,16] found a pulse energy of 4 mJ and a pulse width of 150 μs as the optimal parameters for Erbium:YAG LTA in human donor eyes. In a primate study, pressure-lowering efficacy of LTA was reassured, but within 4 months following laser surgery, the intraocular pressure again recovered to the preoperative level and the laser-induced craters refilled with white scar tissue [15]. In another animal study, scarring processes up to 60 days following experimental Erbium:YAG laser ablation of trabecular meshwork in rabbits were histopathologically documented, also demonstrating a refilling of the ablation areas [21]. Although disappearance of gonioscopically visible laser effects in the treated area of the trabecular meshwork within 1 year after LTA suggests refilling by scar tissue or pigment granules likewise in humans, the time course of IOP showed no statistically significant functional relapse, even under consideration of the medication score. Possibly the repair mechanisms in the relatively old glaucoma patients develop very slowly and uncompletely in comparison to the animal models, or the new scar tissue replacing the glaucomatous trabecular tissue in the treatment area still guarantees a certain improvement of outflow facility compared to preoperative state. The last hypothesis might be supported by the histological findings of newly built

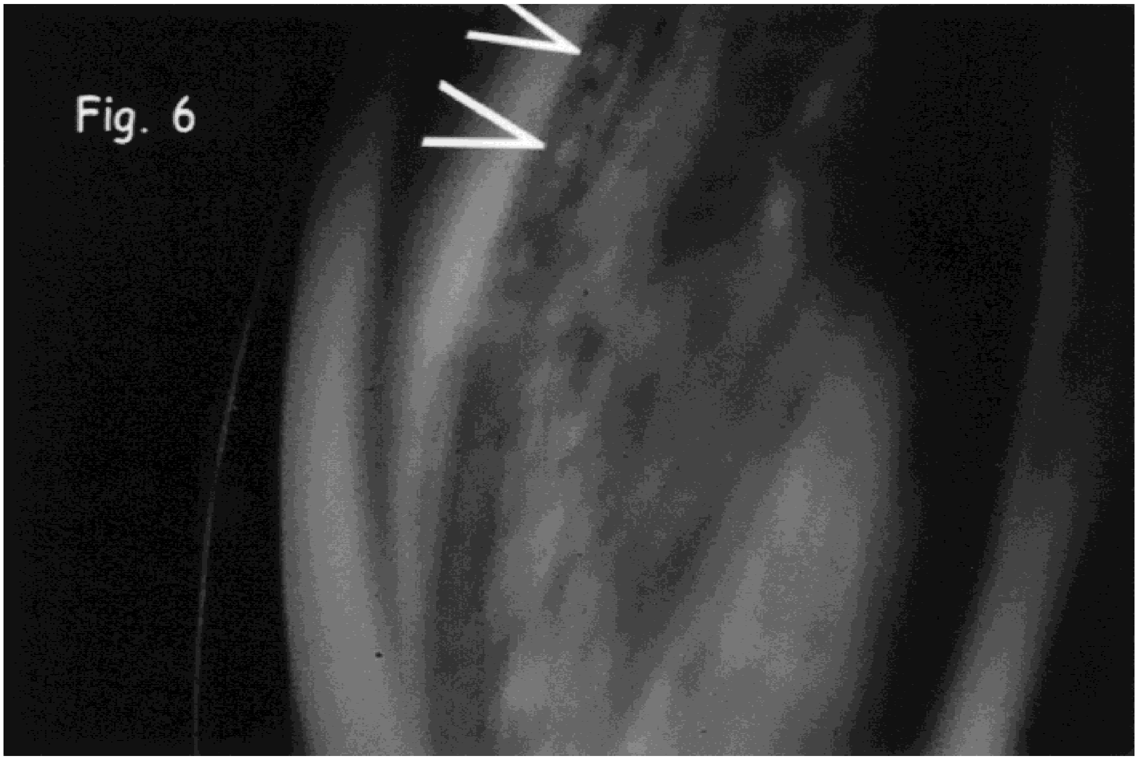

Fig. 6. A representative case (primary open-angle glaucoma): Gonioscopy 8 weeks following Erbium:YAG laser trabecular ablation. The ablation craters can be identified by a localized loss of pigmentation within the trabecular meshwork (see arrows); 12 months later these craters are hardly recognizable.

vessels within the scar area after pressure-reducing laser treatment in animals [21–23].

Contrary to ab-externo Erbium:YAG laser sclerostomy, the conjunctival situation is not worsened by LTA due to its ab-interno approach. This is of major importance in many patients with refractory glaucoma since they might need further filtering procedures later on. Another advantage of Erbium:YAG laser trabecular ablation is the fact that no ocular hypotony in the early postoperative period occurs as typically seen after laser sclerostomy bearing the risk of flattened anterior chamber, choroidal detachment, and subsequent cataract formation [6].

In 4 of our 11 patients, IOP could not be sufficiently controlled by LTA despite additional topical therapy, although in one of these patients maximum IOP dropped down from 44 mmHg to 26 mmHg. The future employment of LTA in the surgical therapy of open-angle glaucoma has to show whether these failures can be avoided by an increased area of laser treatment. A postoperative IOP level below 15 mmHg cannot be expected after Erbium:YAG LTA because the outflow resistance of the scleral tissue and episcleral vessels is not influenced by trabecular ablation. Therefore, we now perform LTA preferentially in glaucoma patients with a preoperative IOP higher than 30 mmHg despite topical medication. In these patients Erbium:YAG LTA is a surgical intervention that offers significant reduction of IOP to a satisfactory level with a relatively minor risk profile.

In conclusion, ab-interno Erbium:YAG laser trabecular ablation represents a promising option of glaucoma surgery in patients with high-pressure open-angle glaucoma, avoiding the typical disadvantages of laser sclerostomy as overfiltration and conjunctival scarring.

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